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Update on Tritium Management at Fermilab

Presentation to Fermilab Community Advisory Board

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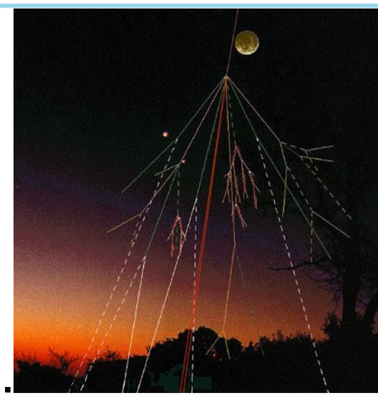
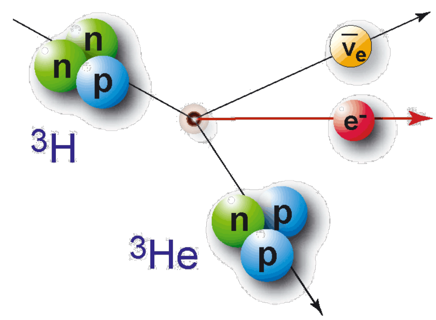
September 22, 2016

What is tritium?

- Tritium (^3H) is a weakly radioactive form of hydrogen with a half-life of 12.3 years.
- In nature, tritium is produced when cosmic particles hit the atmosphere.
- At Fermilab, small quantities of tritium are the byproduct of accelerator operations.



- Its decay emits particles of very low energy that cannot penetrate the skin.



- Tritium can only be harmful if people drink water with high levels of tritium over many years.
- Tritium does not build up in biological tissues; the biological half-life for tritiated water (HTO) is about 12 days.

Where does tritium come from at accelerators?

- High-energy protons hitting or traveling through materials produce tritium (^3H).
- Typical materials used in experiments at Fermilab: iron, concrete, carbon, air, water, etc.
- When protons or other particles hit nuclei in the atoms in materials, they "shatter" these nuclei into pieces.
- Some of the pieces left over are stable nuclei.
- Others are radionuclides, including tritium (^3H) atoms.
- Upon exposure to air, the ^3H atoms combine with oxygen to make HTO molecules (tritiated water), just like the familiar H_2O.
- HTO "water" moves just like regular water.

Monitoring water for presence of tritium

- Fermilab has had an environmental monitoring program for about 40 years.
- In 2005, the program found for the first time tritium in surface water on the Fermilab site, at very low levels.
- We immediately informed the regulatory agencies, our neighbors and employees and the public.
- Levels were and continue to be well below regulatory limits (Finding: less than 20 pCi/ml; Regulatory limit: 1,900 pCi/ml).
- We strive to keep the tritium discharges as low as reasonably achievable, keep the public informed, and seek input on our plans and goals.

How surface water at Fermilab connects to the community

- The Fermilab site has numerous ponds and is the origin of Indian Creek and Ferry Creek; Kress Creek runs through, too.
- Fermilab uses water to cool accelerators and other equipment.
- Our pond system is part of an "industrial cooling water system" (ICW).
- 250,000,000 gallons!
- No one drinks our pond water; it's fine for folks to fish in it.

Standards for surface water

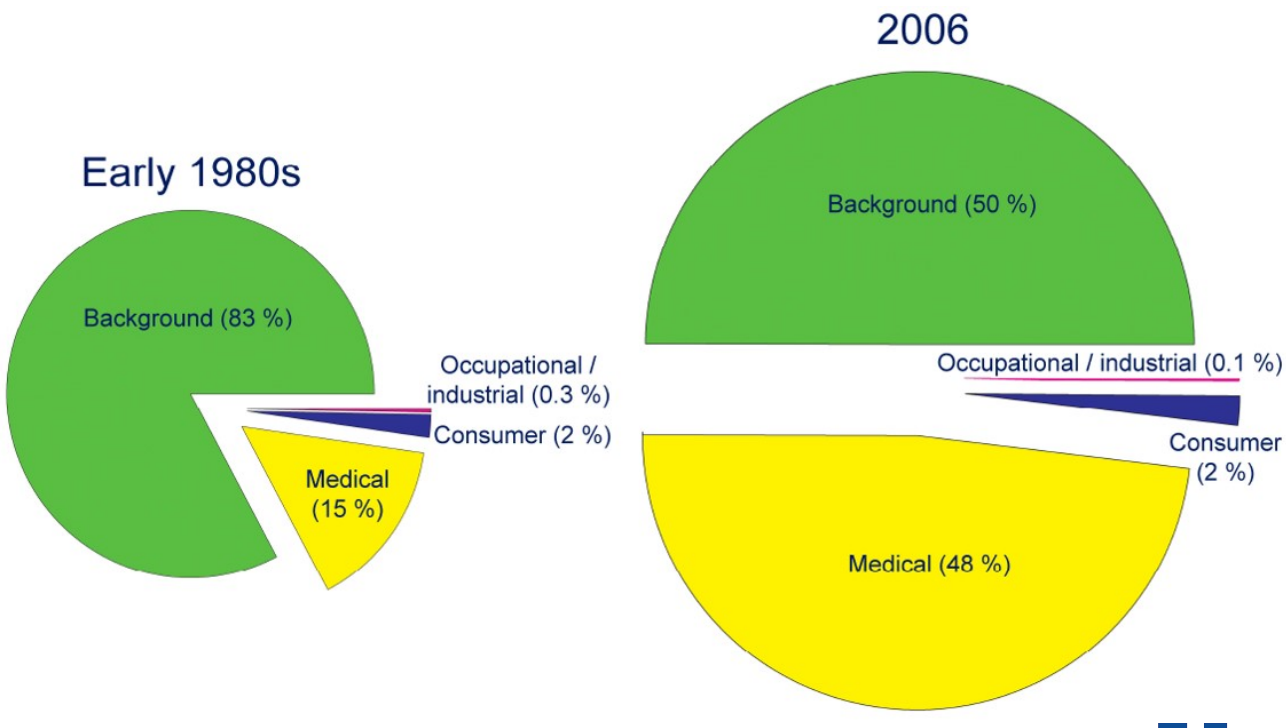
- DOE Surface water limit: 1900 pCi/ml (picocuries per milliliter).
- Levels that we measure in surface water on site: less than 20 pCi/ml.
- Rainwater is 0.16 to 0.32 pCi/ml, due to cosmic rays and leftovers from nuclear weapons tests.

What does this standard mean?

- 1 picocurie (pCi) = 0.037 atoms decaying each second.
- Threshold for measurement is usually taken to be 1 pCi/ml.
- A user of 1900 pCi/ml water for their household water source full time would receive a radiation dose of 100 mrem each year.

Radiation doses

- Radiation we all receive: U.S. Average is 620 mrem each year, about half from natural and the remainder from man-made sources, mostly medical.



Fishing at Fermilab? – not a concern!

- If someone were to catch and eat 50 lbs of fish each year, compared to a national average of 18 pounds.
- And, if our ponds were at 1900 pCi/ml of tritium,
- Their dose would be only 3.34 mrem, even if no water is cooked out of the fish!
- Levels in all ponds are less than 20 pCi/ml.
- We see no need to restrict site access!

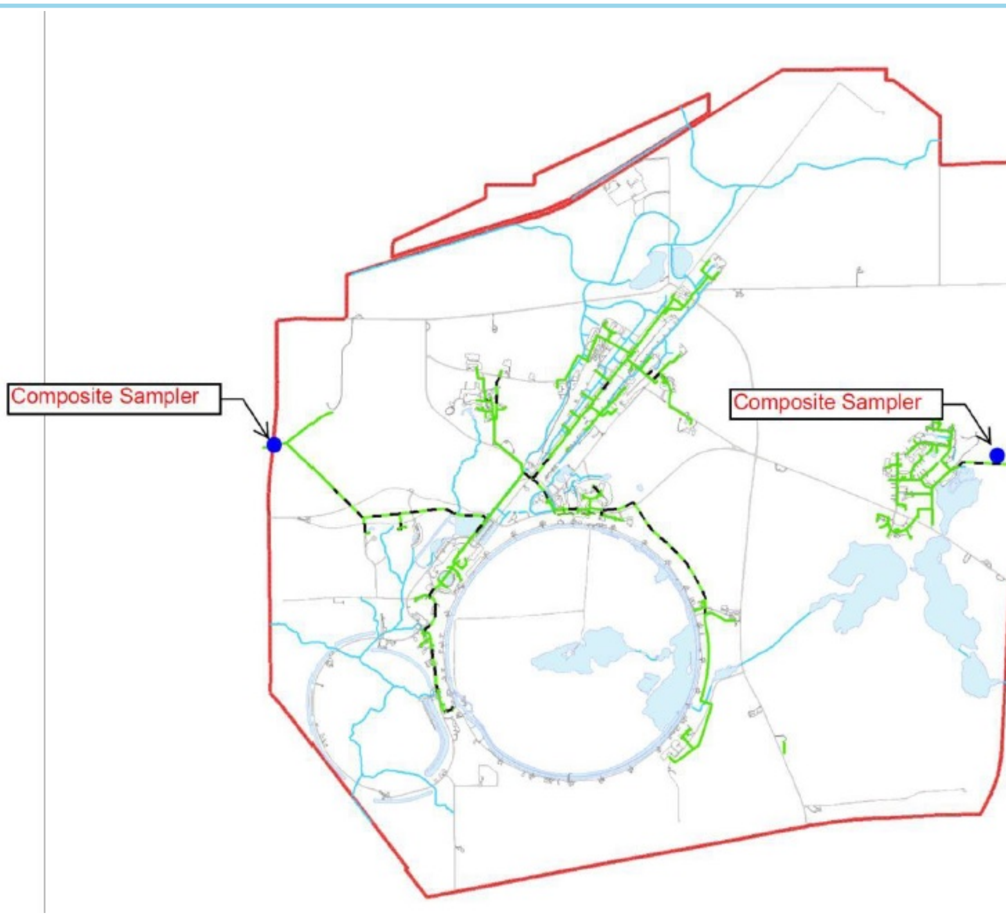
Requirements for drinking water

- We must protect Illinois Class 1 Groundwater (i.e, those considered by Illinois to be “useful” for drinking water)
- Must stay below 20 pCi/ml in Class 1 aquifers.
- A user of 20 pCi/ml water for their household water source is assigned a dose of 4 mrem each year by U. S. EPA.
- **We have never found tritium in Class 1 Groundwater or drinking water, and we design and operate our experiments so that any tritium produced stays out of drinking water.**
- Fermilab employs a hydrogeologist on its staff.

Requirements for sewers

- A limit of 9500 pCi/ml applies to sewers (DOE Order 458.1).
- We have found less than 20 pCi/ml in sewage that goes to Batavia, and no tritium in sewage that goes to Warrenville.
- A limit of 5 Ci to the total amount of tritium discharged to the sewers each year also applies. We discharged 0.3 Ci in 2015.
- Sewer discharges must be reported to local municipalities (Batavia, Aurora, etc.) annually by the Department of Energy.
- The DOE site office at Fermilab does this every year after the end of the Federal *fiscal* year, i.e. after September 30.
- We reported the low levels of tritium in sewers going to Batavia (see upcoming slide).

Monitoring tritium in the sewer system



Monitoring tritium in the sewer system (cont'd)

- Since 2012, we have routinely been seeing measurable tritium concentrations in the Batavia, and only the Batavia, sewer system.
- The low concentrations found track along with the tritium monitoring of the NuMI beamline.
- Sewer discharge goes to Batavia sewage treatment plant, then into the Fox River, where the low concentrations get very much diluted.
- Met with officials in Batavia and Aurora to inform and discuss
- City of Aurora uses Fox River water for part of its water supply.
  – Aurora measured the tritium concentration in the river and found that it is less than 0.01 pCi/ml.

Sewer discharge data reported in 2015

2015 Release to Sanitary Sewers

Total Tritium	**0.277 Curies**
Average Concentration	2.32 pCi/ml
Highest Concentration	6.00 pCi/ml
Total Sanitary Volume	27450 kGal

Reminder: 5 Ci annual discharge limit

Requirements for air emissions

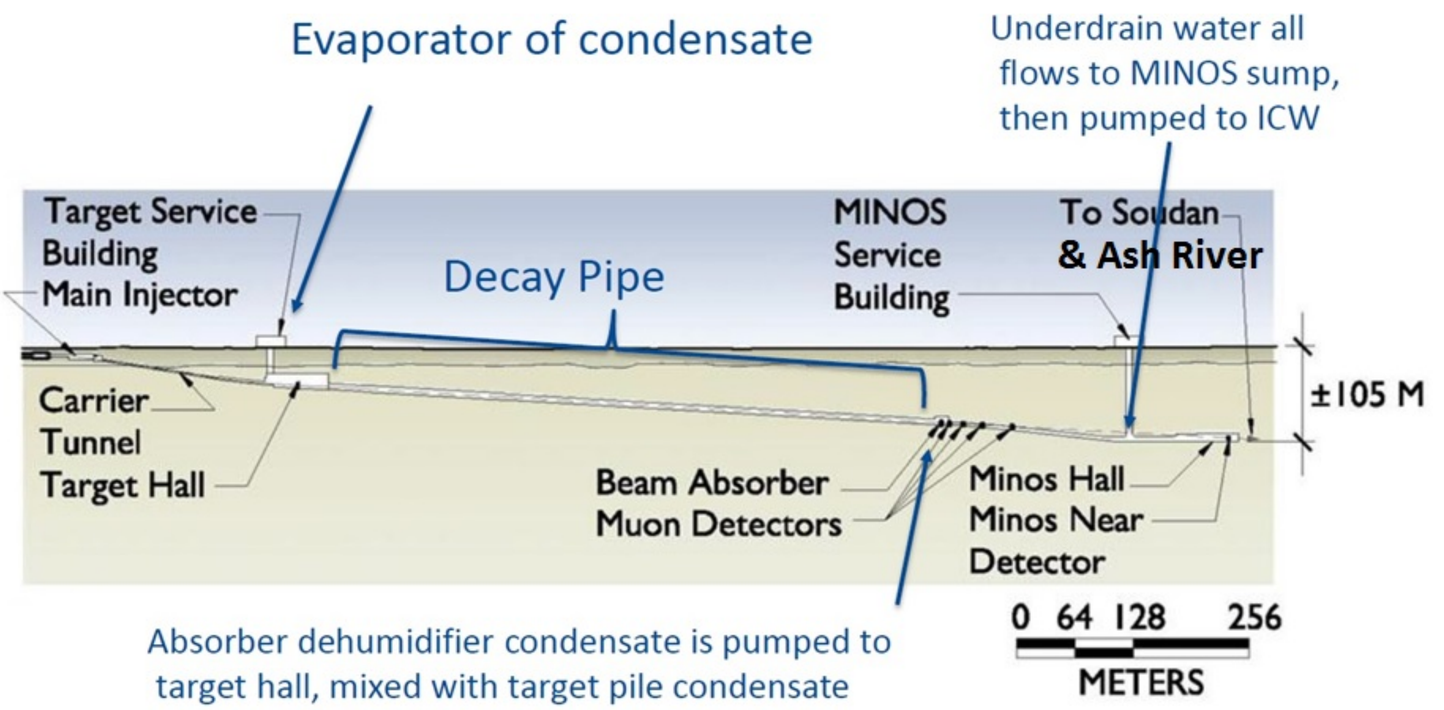
- Limits apply to airborne emissions of radionuclides.
- U.S. EPA limits our emissions to those that would result in a dose of 10 mrem to someone on our property line each year.
- We stay well below 0.1 mrem each year, for all radionuclides, not just tritium.
- We sample our ventilation exhausts for radionuclides and identify the quantities and types of radionuclides emitted.
- Verified by instrumentation that operates whenever our accelerators are operating.

History of tritium management at Fermilab

- First intensity frontier beamline, Neutrinos at the Main Injector (NuMI), started up in spring of 2005.
- Routine monitoring found measurable tritium in the ponds in late 2005, a Fermilab "first".
- Resulted in establishment of a Tritium Task Force.
  - Worked with state and federal regulators.
  - Worked toward improvements, lowering the concentrations as low as reasonably achievable.
  - Increased surveillance monitoring and sampling.
  - Communicated with the public.
- Improvements were made:
  - Improved water management at NuMI.
  - Met with the public in numerous forums.
  - Established the website: http://fnal.gov/pub/tritium/index.html.

Management of tritium at the NuMI beamline

- One of two beamlines with intense proton beams

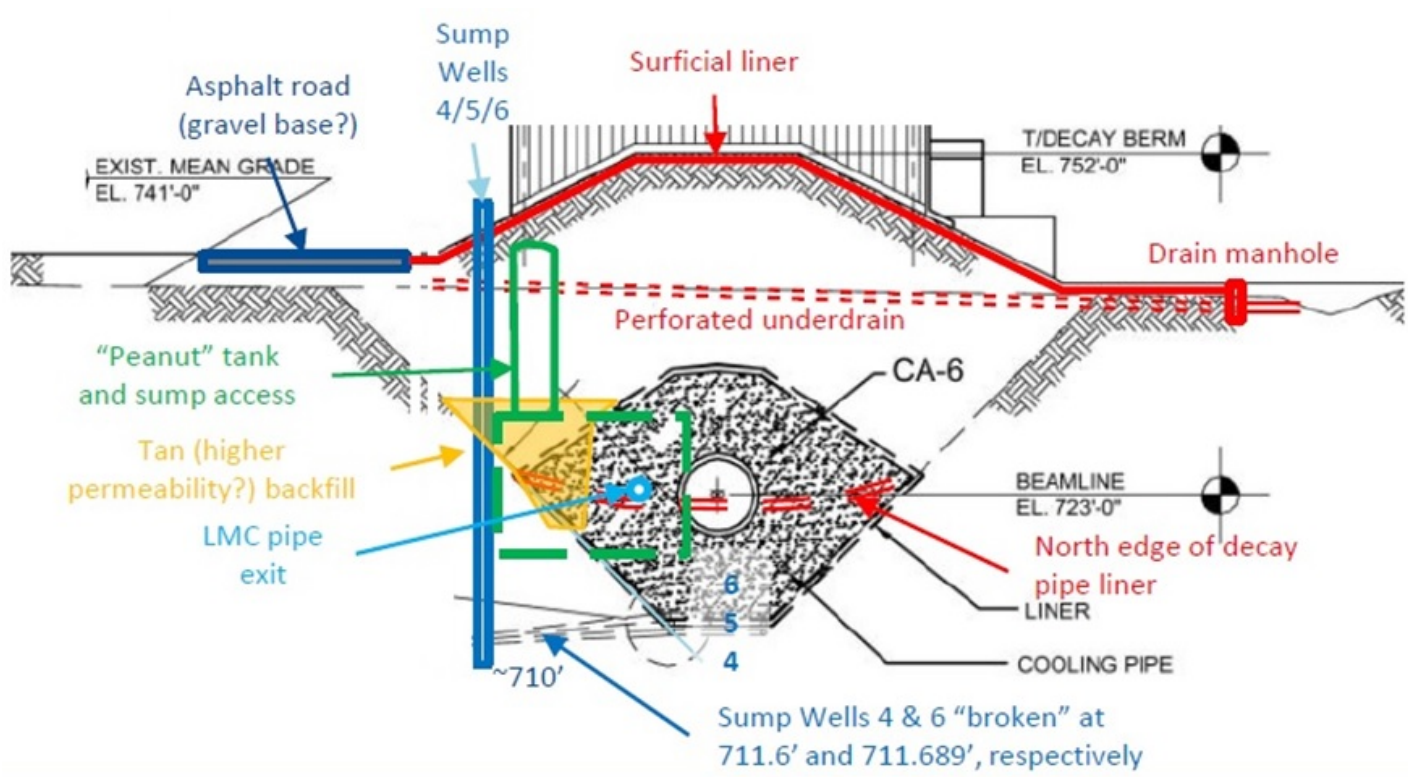


Management of tritium at the NuMI beamline

- ^3H is produced in the shielding, mostly closest to the beam.
- ^3H migrates through shielding (even steel!), gets into air, becomes HTO.
- Tritiated water vapor condenses in the cool tunnel (about 53 deg. F) and goes downhill to the Holding Tank.
- It is designed to draw water inward to protect groundwater.
- Holding Tank water is routed to the Central Utility Building where it cools other water, some is evaporated, remainder goes into the Industrial Cooling Water system.
- Have been managing the tritium with large-scale dehumidifiers (about $500k-worth) with good success.
  - Gets some HTO out of tunnel air and hence keeps it from getting into the sump pump and surface water.
  - The dehumidification condensate gets evaporated.

Management of tritium at the Booster Neutrino Beam

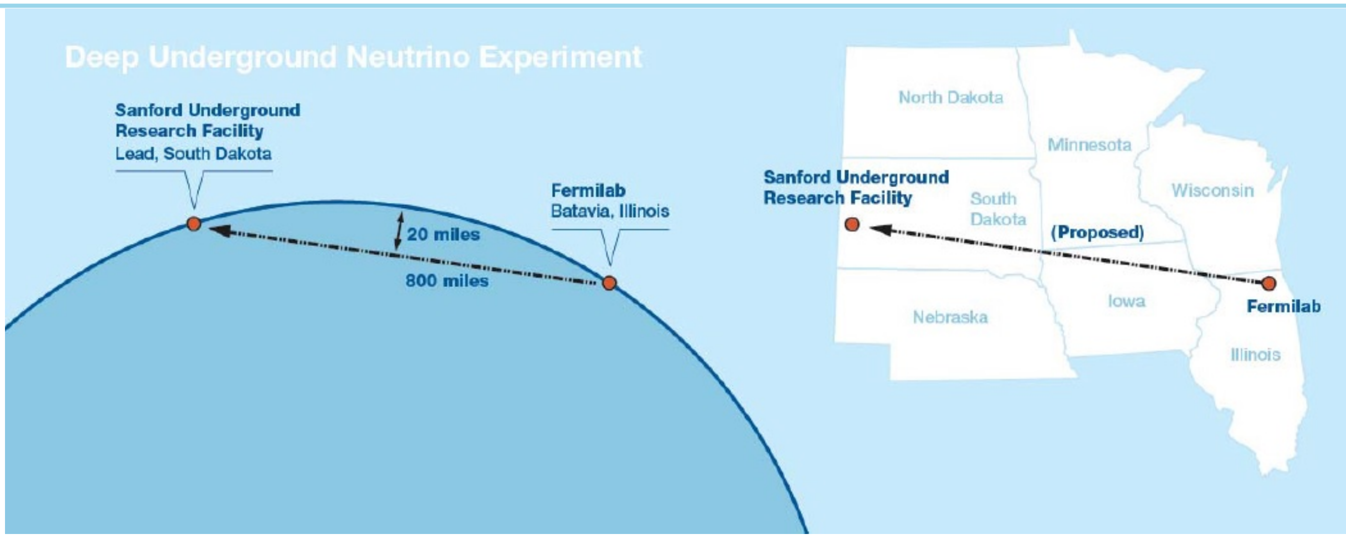
- Second of two beamlines with intense proton beams



Management of tritium at the Booster Neutrino Beam

- Production of tritium not much different than at NuMI.
- The shielding scheme is different and the beam is much closer to the surface.
- Challenge: Rainwater gets into the shielding, leads to the additional production of tritiated water (HTO).
- In 2013 an engineered liner was placed over most of the region as an "umbrella" to limit water inflow and reduce water discharges.
- Rainwater water still gets in and we have to manage the tritiated water that gets pumped out.
- Our civil engineers are working on improvements.

Future experiments: More proton beam



- We are planning a new neutrino beamline called the Long Baseline Neutrino Facility (LBNF) to send neutrinos to the DUNE experiment in South Dakota.
- This will be a new neutrino beam to operate after NuMI is retired.
- Improved tritium management is a major focus on the design of this new, higher beam power facility.

Current status of tritium management at Fermilab

- Due to improvements made in the past 10 years, concentrations have remained far below the regulatory standards even though we are operating today with much higher proton beam intensities.
- As beam power will continue to rise, we seek to make further improvements to keep tritium levels well below regulatory limits and as low as reasonably achievable.
- Minimizing or eliminating rainwater infiltration at BNB beamline is a priority.
- Aim to fully understand the connection between tritium in the Industrial Cooling Water system and the low levels of tritium in the sewer system and then keep those levels as low as reasonably achievable.

Brought in external experts in June 2016:

- Commissioned by Fermilab Director Nigel Lockyer.
- Conducted June 20-22, 2016.
- Led by Katherine Gregory, Engineer, Rear Admiral, US Navy Retired
  - Comprised of 5 outside experts in hydrogeology and radiation protection.
  - Looked at lots of data and "field conditions".
  - Toured facilities of interest.
  - Reviewed the history, and our actions taken to date.

External Review observations (Summary)

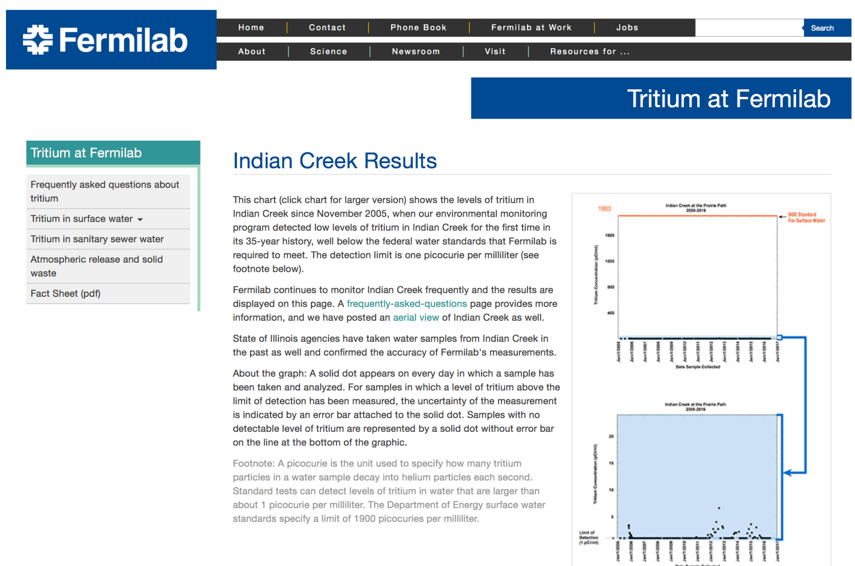
- Fermilab has a good grip on the details, but needs to move toward a more strategic approach.
- Approach to improvements to tritium management at NuMI beamline are well-advanced and plans for mitigation should be implemented.
- Approach to fixing rainwater infiltration at the BNB beamline needs more engineering help
- Conduct an external review of Long Baseline Neutrino Facility (LBNF)
- Implement a more strategic approach to fully understand tritium levels in the sewers.
- Suggested some alternative approaches.

Response in July 2016

- Director Nigel Lockyer chartered a new Tritium Task Force.
- Task Force Chair: Chief Safety Officer Martha Michels
- Task Force Deputy Chair: Senior Radiation Safety Officer (me!)
- Has “panels” with specific assignments.
- Developing a comprehensive plan (summarized):
  - Understand NuMI and its long term prospects.
  - Develop a more global strategy for BNB.
  - Review design plans for managing tritium at LBNF.
  - Review design plans for accelerator upgrades.
  - Develop a strategy to understand the sewer-ICW connection.
  - Develop a sampling strategy with clear objectives.
  - Develop a communications plan.

Keeping the public informed

- We held public LBNF/DUNE Environmental Assessment meetings in 2015, which included tritium production.
- We seek input from you: the Community Advisory Board.
- We update and post tritium data on our public tritium webpages.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Tritium at Fermilab

Tritium at Fermilab
- Frequently asked questions about tritium
- Tritium in surface water
- Tritium in sanitary sewer water
- Atmospheric release and solid waste
- Fact Sheet (pdf)

Indian Creek Results

This chart (click chart for larger version) shows the levels of tritium in Indian Creek since November 2005, when our environmental monitoring program detected low levels of tritium in Indian Creek for the first time in its 35-year history, well below the federal water standards that Fermilab is required to meet. The detection limit is one picocurie per milliliter (see footnote below).

Fermilab continues to monitor Indian Creek frequently and the results are displayed on this page. A frequently-asked-questions page provides more information, and we have posted an aerial view of Indian Creek as well.

State of Illinois agencies have taken water samples from Indian Creek in the past as well and confirmed the accuracy of Fermilab's measurements.

About the graph: A solid dot appears on every day in which a sample has been taken and analyzed. For samples in which a level of tritium above the limit of detection has been measured, the uncertainty of the measurement is indicated by an error bar attached to the solid dot. Samples with no detectable level of tritium are represented by a solid dot without error bar on the line at the bottom of the graphic.

Footnote: A picocurie is the unit used to specify how many tritium particles in a water sample decay into helium particles each second. Standard tests can detect levels of tritium in water that are larger than about 1 picocurie per milliliter. The Department of Energy surface water standards specify a limit of 1900 picocuries per milliliter.

Questions for the CAB

- Members of the Community Advisory Board are one of Fermilab’s connections to the community.
- How should we keep the community informed and maintain a dialogue?
- What questions and recommendations do you have?
- Are there specific groups or persons we should reach out to?
- Do you consider us a good steward of the Fermilab site?